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Pediatric Trauma BIG Score: Predicting Mortality in Children After Military and Civilian Trauma

WHAT'S KNOWN ON THIS SUBJECT: There is little published on the epidemiology of pediatric trauma in the recent conflicts in Iraq and Afghanistan, and no widely accepted and validated pediatric trauma score exists for children.

WHAT THIS STUDY ADDS: This study describes the epidemiology of pediatric trauma in a military setting, uses regression methodology to derive a mortality prediction score, and further validates this score in a separate civilian trauma population.

abstract

OBJECTIVE: To develop a validated mortality prediction score for children with traumatic injuries.

PATIENTS AND METHODS: We identified all children (<18 years of age) in the US military established Joint Theater Trauma Registry from 2002 to 2009 who were admitted to combat-support hospitals with traumatic injuries in Iraq and Afghanistan. We identified factors associated with mortality using univariate and then multivariate regression modeling. The developed mortality prediction score was then validated on a data set of pediatric patients (≤18 years of age) from the German Trauma Registry, 2002–2007.

RESULTS: Admission base deficit, international normalized ratio, and Glasgow Coma Scale were independently associated with mortality in 707 patients from the derivation set and 1101 patients in the validation set. These variables were combined into the pediatric "BIG" score (base deficit + [2.5 × international normalized ratio] + [15 − Glasgow Coma Scale), which were each calculated to have an area under the curve of 0.89 (95% confidence interval: 0.83–0.95) and 0.89 (95% confidence interval: 0.87–0.92) on the derivation and validation sets, respectively.

CONCLUSIONS: The pediatric trauma BIG score is a simple method that can be performed rapidly on admission to evaluate severity of illness and predict mortality in children with traumatic injuries. The score has been shown to be accurate in both penetrating-injury and blunt-injury populations and may have significant utility in comparing severity of injury in future pediatric trauma research and quality-assurance studies. In addition, this score may be used to determine inclusion criteria on admission for prospective studies when accurately estimating the mortality for sample size calculation is required. *Pediatrics* 2011;127: e892–e897

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KEY WORDS

wounds and injuries, pediatrics, shock, outcome assessment, prognosis

ABBREVIATIONS

ISS—Injury Severity Score
INR—international normalized ratio
RTS—Revised Trauma Score
ASPTS—Age-Specific Pediatric Trauma Score
TRISS—Trauma and Injury Severity Score
PAAT— Pediatric Age-Adjusted Trauma and Injury Severity Score
OR—odds ratio
GCS—Glasgow Coma Scale
CI—confidence interval

Dr Matthew A. Borgman was responsible for study conception and design, data analysis, and drafting of the article. Dr Marc Maegele was responsible for study design, data analysis, and article review. Dr Charles E. Wade was responsible for study design, data analysis, and article review. Dr Lorne H. Blackbourne was responsible for study design and article review. Dr Philip C. Spinella was responsible for study conception and design and drafting and reviewing the article. All authors approved the final version of this manuscript.

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Injury and violence account for ~950 000 deaths annually in children younger than 18 years of age in the world and is the leading cause of death in children and adults aged up to 44 years in developed countries.[1–3] There is no common or consistently used validated pediatric severity-of-illness score for pediatric trauma patients. Some scoring systems are primarily for prehospital triage. They typically are easy to calculate and are meant to aid emergency service technicians in directing their patients to the appropriate trauma service level of care. Other scoring systems, those that assess severity of illness or predict mortality, often are complex, utilize many variables, and are modifications of adult scoring systems.[4]

The Injury Severity Score (ISS) is the most widely used system and characterizes injury based on the 3 most severely injured body regions. The ISS has been validated in children[5]; however, it takes trained personnel to review the medical chart and injury pattern to calculate.

The purpose of this study was to design a scoring system with variables rapidly available on admission using regression methods based on data from a unique population of critically injured children in a military setting that could be used both to assess severity of injury and predict mortality. Second, we validated this scoring system externally on an entirely different civilian population of children.

MATERIALS AND METHODS

Datasets

For the model derivation, a retrospective review of the Joint Theater Trauma Registry from 2002 to 2009 was performed. The Joint Theatre Trauma Registry was established by the Department of Defense to collect comprehensive data on all personnel, military and civilian, admitted to military treatment facilities within Iraq and Afghanistan. It is maintained at the US Army Institute of Surgical Research in San Antonio, Texas. Penetrating injury was defined as those occurring from gunshot wounds, whereas penetrating blast injuries was defined as injury from shrapnel, explosions including improvised explosive devices, landmines, and mortars. The institutional review board at Brooke Army Medical Center, San Antonio, Texas, approved this study. To externally validate the model score, a separate analysis was conducted on the Trauma Registry of the Deutsche Gesellschaft für Unfallchirurgie (TR-DGU), German Trauma Society. This is a prospective multicenter database with 145 centers; 128 registries from Germany contribute to the database. A retrospective review was performed on this database from 2002 to 2007 on all patients admitted with trauma who were younger than 18 years. Baseline demographics, vital signs, and laboratory values were evaluated from this population.

Subjects

Inclusion criteria were all children who were admitted with trauma, aged less than 18 years, who had recorded any baseline vitals, to include heart rate and systolic blood pressure, and coagulation labs (prothrombin time and international normalized ratio [INR]).

Statistical Analysis

Univariate analyses were performed for baseline demographics, vital signs, and laboratory values correlating with mortality. A reverse, stepwise, multivariate logistic regression was performed for those variables that were associated with mortality with a P value $<.05$, given the number of correlating variables. Variables were removed before this analysis, after testing for colinearity with Spearman correlation. Additional tests for effect modification also were performed. For those variables found to be independently predictive of mortality, a score was derived on the basis of the regression coefficients. This score was first evaluated on a receiver-operating curve for mortality compared with the regression value, ISS, Revised Trauma Score (RTS), Age-Specific Pediatric Trauma Score (ASPTS), and Pediatric Age-Adjusted Trauma and Injury Severity Score (TRISS) (PAAT).[6–11] The score was then evaluated for sensitivity, specificity, and predicted mortality, as well as observed and expected deaths for each quintile score group. The model score was then evaluated on this population using a receiver-operating curve analysis. Observed and predicted mortality were then calculated for each quintile of score distribution. Statistical analyses were performed using SPSS version 15.0 (SPSS, Chicago, IL).

RESULTS

In the model derivation set in the Joint Theatre Trauma Registry, of 1995 patients evaluated there were 707 with vital signs and laboratory values as described in the methods available for analysis. The overall mortality was 8.9% (63 of 707) with a median (interquartile range) ISS of 10 (5–19). Mortality was not significantly different from those excluded from the analysis because of incomplete data (8.5% [109 of 1288]); however, the ISS was slightly lower in these patients (median: 9 [interquartile range: 4–16]; $P < .05$). The median age was 9 years (interquartile range: 5.5–12) and 75% were male. The distribution of injury was 20% were blunt, 28% were penetrating, 44% were from penetrating blast injuries, and 8% were from burns. This was significantly different from those excluded from the analysis, where there were 27% blunt injuries, 22% penetrating injuries, 36% penetrating blast in-

TABLE 1 Variables Associated With Mortality in the Score Derivation Set

Variable	*n*	Survivors, Median (Interquartile Range), $n = 644$	Nonsurvivors, Median (Interquartile Range), $n = 63$	P[a]
Age	707	9 (6–12)	7 (4–12)	.029
Male	707	75% (485 of 644)	68% (43 of 63)	NS[b]
Systolic blood pressure, mmHg	683	118 (105–130)	112 (92–122)	.003
Heart rate, bpm	693	117 (102–139)	134 (102–157)	.16
Respiratory rate	488	24 (20–30)	31 (22–44)	.001
Hematocrit, %	690	34.0 (29.7–38.2)	31.6 (26.5–35.4)	.001
Platelets, ×1000	692	334 (256–425)	252 (158–331)	<.001
INR	707	1.2 (0.9–1.4)	1.8 (1.4–2.4)	<.001
pH	706	7.33 (7.28–7.38)	7.20 (7.07–7.32)	<.001
Base deficit	707	4 (2–6)	8 (5–12)	<.001
GCS total	707	15 (13–15)	3 (3–11)	<.001
GCS verbal	682	5 (5–5)	1 (1–3)	<.001
GCS eye	682	4 (4–4)	1 (1–4)	<.001
GCS motor	682	6 (6–6)	1 (1–6)	<.001
ISS 1998	707	10 (5–18)	25 (16–29)	<.001
ISS 2005	707	10 (5–18)	25 (14–29)	<.001
RTS	488	7.84 (7.55–7.84)	5.67 (4.09–7.55)	<.001

Data are presented as medians (interquartile ranges) or as percentages. NS indicates not significant.
[a] Kruskal-Wallis test.
[b] χ^2 test.

juries, and 15% burn injuries ($P < .01$). Baseline variables associated with mortality are noted on Table 1. After multivariate logistic regression for mortality, variables that remained in the model were base deficit odds ratio (OR): 1.15, INR OR: 2.19, and Glasgow Coma Scale (GCS): OR 0.82 ($P < .001$) (Table 2). The model score, termed "BIG" score, was then calculated as follows: (base deficit) + (2.5 × INR) + (15 − GCS). The Hosmer-Lemeshow goodness-of-fit test for this BIG score resulted in a *P* value of .69 with 8 degrees of freedom.

The receiver-operating curve analysis is noted on Fig 1. The BIG score yielded the highest area under the curve of 0.89 (95% confidence interval [CI]: 0.83–0.95) compared with the RTS of 0.81 (95% CI: 0.70–0.90), the ASPTS of 0.81 (95% CI: 0.72–0.90), the PAAT of 0.75 (95% CI: 0.64–0.86), and the ISS of 0.74 (95% CI: 0.62–0.85).

TABLE 2 Multivariate Logistic Regression for Mortality

Variable	β	OR	*P*
Base deficit	0.131	1.15 (1.1–1.2)	<.001
INR	0.782	2.19 (1.5–3.3)	<.001
GCS	−0.195	0.82 (0.78–0.87)	<.001

The predicted mortality can be calculated from the BIG score as follows: predicted mortality $= 1/(1+e^{-x})$, where $x = 0.2 \times (\text{BIG score}) - 5.208$. Predicted and observed mortality were similar per BIG score quintiles and are noted in Fig 2. For a hypothetical patient with a BIG score of 26 (eg, base deficit 10, INR 3.6, GCS 6), the predicted mortality is 50% with a positive predictive value of 65%, negative predictive value of 93%, and specificity of 99% in the derivation set.

There were 1101 patients analyzed in the score validation set of the German Trauma Registry. The overall mortality was 11.6% (128 of 1101) with a mean ISS of 24 (±15) and a median of 22 (interquartile range: 13–29). The median age was 15 years (interquartile range: 10–16) and 66% male. The distribution of injury was 96.6% blunt, 3.1% penetrating, with 0.3% missing. Baseline variables associated with mortality are noted in Table 3. Figure 1 shows the receiver-operating curve for mortality, which yielded an area under the curve of 0.89 (95% CI: 0.87–0.92). There is no significant difference between predicted and observed mortality in each BIG score group (using the same quintiles as the derivation set) (Fig 3).

DISCUSSION

The pediatric trauma BIG score is a novel tool using variables rapidly available on admission for assessing severity of illness and predicting mortality. The BIG score was developed on a group of injured children in a military setting, with an area under the receiver-operating curve of 0.89 (95% CI: 0.83–0.95). The area under the curve was similarly 0.89 (95% CI: 0.87–0.92) for an entirely different, civilian European pediatric population, 96.6% of whom had blunt injuries.

The Pediatric Trauma Score[10,11] was not developed on the basis of methods that adjust or account for confounding, such as regression, but rather is a tool based on weight, systolic blood pressure, wounds, fractures, and assessments of the airway and central nervous system. Although the Pediatric Trauma Score has been shown to correlate with mortality, it does not perform as well as adult scoring systems, such as the RTS.[4,7] The RTS utilizes the GCS, systolic blood pressure, and respiratory rate, along with regression coefficients to calculate a score, which can be used for triage, in the simplified form, or for outcome analysis. An adult system to characterize anatomic injury is the ISS.[6] Of note, it takes trained personnel to review charts and calculate this score, and it typically is outperformed by physiologic scores in predicting mortality.[12] The two scoring systems most used to show adult severity of injury are the TRISS (which combines RTS, ISS, and age) and, more recently, the ASCOT (A Severity Classification of Trauma)

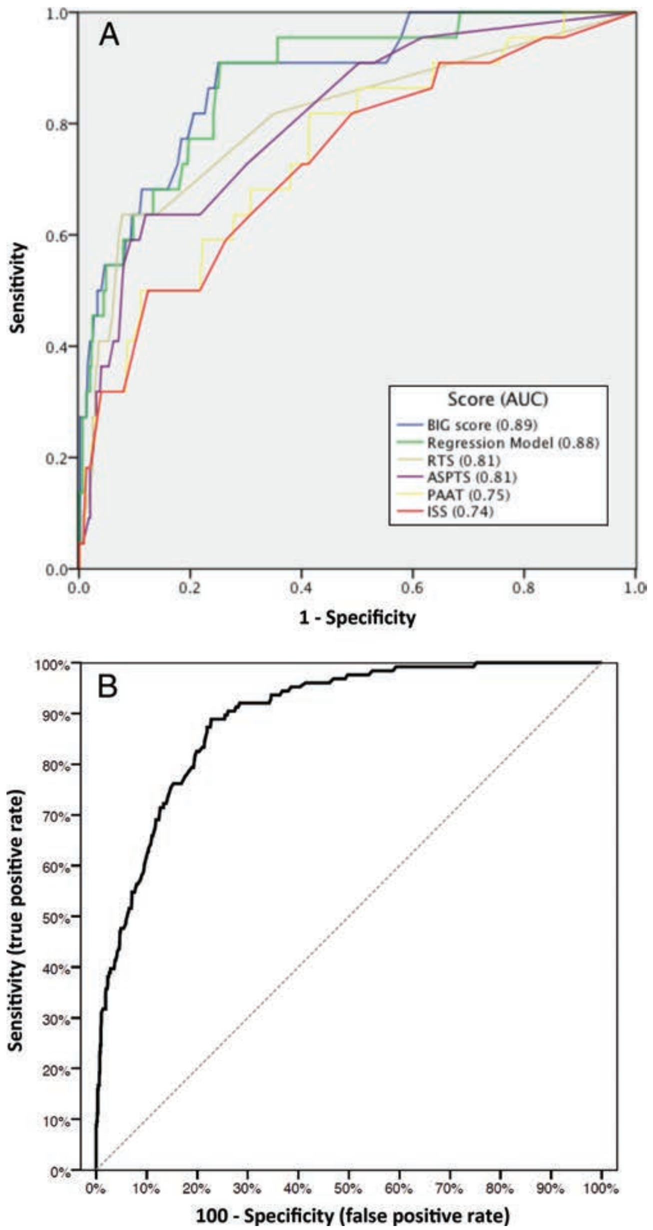

FIGURE 1
A, receiver-operating curves for mortality in the score derivation and validation set. AUC indicates area under curve. B, validation set (German Trauma Registry) area under the curve = 0.89.

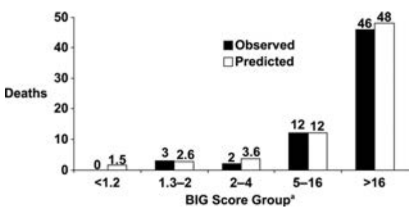

FIGURE 2
Observed and predicted mortality by the BIG score quintile in the derivation set. [a]No statistical difference between observed and expected (χ^2 test).

score (which combines injury location, RTS, and age).[13]

Three notable scoring systems have been specifically developed to predict mortality in pediatric trauma. The Pediatric Risk Index[14] is defined on the basis of the ratio of ISS to GCS and Pediatric Trauma Score. This score is complex, uses 12 individual variables, and has been outperformed by newer measures of severity of injury.[4] The ASPTS[8] was later revised to the PAAT by the same authors.[9] The ASPTS includes GCS, the *z* scored systolic blood pressure, heart rate, and respiratory rate and adds the ISS. The PAAT score has outperformed the TRISS in pediatric patients but has not been externally validated or confirmed by other investigators.[4] The BIG score outperformed the ASPTS and PAAT and is easier to calculate. It also can be calculated quickly on admission, allowing for its use clinically or for clinical trials.

The most common cause of death in adult and pediatric trauma is head injury, which accounts for about half of all deaths.[15–18] All previous scoring systems, including the pediatric BIG trauma score, include GCS or another measure of the central nervous system, which likely enhances the ability of these scores to predict mortality. Hemorrhage is the second leading cause of death in trauma, accounting for ~30% of deaths.[17] Trauma-related hemorrhage is classically described as being driven by the "trauma triad" or "bloody vicious cycle" of hypothermia, acidosis, and coagulopathy.[19,20] More recently, an advance model of trauma-related hemorrhage, called trauma-induced coagulopathy, has been developed.[21,22] This model emphasizes that hypoperfusion can lead to coagulopathy and notes this as ACOTS (acute coagulopathy of trauma shock).[19] Interestingly, the two other components of the BIG score are INR, a measure of coagulopathy (specifically the tissue factor–activated arm of the coagulation cascade), and base deficit, a measure of shock and acidosis. Recent studies[23,24] indicate that the base deficit predicts mortality in pediatric trauma patients. Coagulopathy, as characterized by increased fibrin degradation products, has been shown to predict mortality in children with head trauma.[25] These variables have not been a part of previous scoring sys-

TABLE 3 Variables Associated With Mortality in the Score Validation Set

Variable	*n*	Survivors, Median (Interquartile Range), $n = 973$	Nonsurvivors, Median (Interquartile Range), $n = 128$	P[a]
Age	1101	15 (10–16)	15 (11–16)	NS
Male	1098	66.1% (641 of 970)	69.5% (89 of 128)	<.001[b]
Systolic blood pressure, mmHg	1067	120 (104–130)	100 (78–120)	<.001
Heart rate, bpm	1052	98 (80–110)	100 (80–120)	NS
Respiratory rate	367	15 (12–18)	12 (9–15)	<.001
Hemoglobin, mg/dL	1101	11.4 (9.9–12.8)	9.6 (7.1–11.7)	<.001
Platelets, ×1000	1085	229 (181–287)	181 (129–249)	<.001
INR	1101	1.2 (1.0–1.4)	1.8 (1.4–2.3)	<.001
pH	531	7.34 (7.28–7.39)	7.26 (7.12–7.38)	.001
Base deficit	1101	2.3 (0.4–4.3)	6.0 (2.6–12.2)	<.001
GCS total	1101	13 (7–15)	3 (3–4)	<.001
GCS verbal	1101	4 (1–5)	1 (1–1)	<.001
GCS eye	1101	4 (1–4)	1 (1–1)	<.001
GCS motor	1101	5 (4–6)	1 (1–2)	<.001
ISS	1086	20 (13–29)	43 (29–51)	<.001
RTS	709	6.93 (5.96–7.84)	3.36 (2.19–4.50)	<.001

Data are presented as medians (interquartile ranges) or percentages. NS indicates not significant.

[a] Kruskal-Wallis test.

[b] χ^2 test.

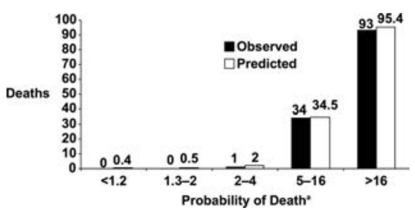

FIGURE 3

Observed and predicted mortality by the BIG score group in the validation set. [a]No statistical differences between observed and predicted (χ^2 test).

tems for trauma patients, making the BIG score unique in that it includes variables that are highly associated with the 2 major causes of death from trauma (brain injury and hemorrhagic shock).

The limitation of the BIG score is that it requires laboratory values to calculate it, unlike previous scoring systems discussed, which are based just on clinical examination findings. Several of these other scores would be difficult to calculate given that they require *z* score normalization of vital signs. The BIG score in a prehospital setting would require an i-STAT or other point-of-care device to obtain INR and base deficit values, which both can be measured within 2 minutes of sampling. Despite this limitation, we would emphasize that a blood gas to obtain base deficit and a coagulation profile should be the part of standard admission labs for severe trauma patients to characterize shock and coagulopathy, which may be underappreciated on the initial assessment.

This study carries the same limitations that are inherent in retrospective reviews that utilize registry data. Particularly, there were many patients excluded in the model derivation data set as a result of missing data, leading to a selection bias of patients who were too well to have labs drawn or perhaps too moribund. As noted, the mortality rate was similar in those excluded, although the ISS score was slightly lower, indicating a selection bias in degree of injury. In addition, those included in the analysis had more penetrating injuries and penetrating blast injuries compared with those who were excluded, in whom blunt injury and burns were slightly more prevalent, indicating another possible source of selection bias. However, these limitations are mitigated by our external validation of this score that performed similarly to the derivation set. An additional limitation is lack of a prospective protocol in the timing of drawing lab data, although all labs are listed as being admission labs.

This study's strength lies in the good performance of the score in very dissimilar populations. The model derivation population included predominantly children with penetrating injury. There is presumably higher incidence of malnutrition in this group affected by war and Third-World poverty, and there was likely longer prehospital time. This is in contrast to the validation set, which is primarily blunt injury from a better socioeconomic climate, and with better emergency services that limit prehospital time and provide good point-of-care resuscitation.

This pediatric trauma BIG score potentially can be used for research purposes in comparing severity of illness across populations and to aid in measuring quality assurance in trauma care. Future prospective studies could evaluate whether early correction of INR or base deficit, components of the BIG score, or advanced aggressive care for those above a certain score improves outcomes in trauma patients. In addition, this score may, on admission, be used to determine inclusion criteria for prospective studies when accurately estimating mortality for sample size calculation is required. Finally, there may be other means to improve on this score in children with traumatic injury, such as novel instruments to evaluate perfusion or head injury[26] or thromboelastography to quickly, and perhaps more accurately, assess coagulopathy.[27,28]

CONCLUSIONS

The pediatric trauma BIG score is a simple method that can be performed rapidly on admission to evaluate se-

verity of illness and predict mortality in children with traumatic injuries. The score has been shown to be accurate in both penetrating injury and blunt injury populations and may have significant utility in comparing severity of injury in future pediatric trauma research and quality-assurance studies.

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